Mechanical Properties Of Sunflower Seeds

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Abstract—Sunflower seed has attracted the researchers' attention because its' high nutrition oil. Shell breaking mechanics characteristics test and analysis of sunflower seeds,as to provide a theoretical basis for the pressing equipment and research on sunflower seeds. Through single factor test and orthogonal test of three factors and three levels, the loading direction,moisture content and loading rate as variable; the shell breaking force,breaking deformation with energy consumption are response index. By compared the significance and differences of the data results, finding the best loading mode of sunflower seeds.By single factor test, it was found that shell breaking force along the Y axial are minimum; breaking deformation and energy consumption along the Z axial are minimum..By orthogonal test, the linear models are established which are as follows:F=-0.29v-1.69c-17.1d+138.4, S=-0.046v+0.011c-0.29d+2.043, E=-0.43v-1.09c-21.1d+112.7. These models can well describe the loading process of the sunflower seeds.The mechanics characteristic test of sunflower seeds provides a necessary mechanical basis for designing and researching of the related machinery and equipment.

Keywords-sunflower seed; shell breaking force; shell breaking deformation; shell breaking energy; linear regression

I. INTRODUCTION

Sunflower seed, which is the fruit of sunflower, one of important oil crops because it contains large amounts of high quality oil[1] .Sunflower seed resources are rich, the annual output of China is more than 1,250,000 tons [2].Sunflower seeds contain protein 21%~30%, grease 28%~32%,better than animal fats and vegetable oils.

Sunflower seeds also contain abundant VE 、 VB6, carotene , which could enhance the health of the human body. It also contains carbohydrAtes (digestible)12.6%, cellulose 2.7%, ash 4.4%,and abundant trace elements, vitamin [3].

During the past few decades, many scholars have done research on sunflower seeds processing, such as isolation and characterization of sunflower protein[4],mathematical model for pressing of sunflower seeds[5],and the digestibility of sunflower meal effect on rabbits[6], and simultaneous extraction of oil and water-soluble pase from sunflower seeds with subcritical water[7]. However, theoretical studies on the mechanical properties of sunflower seeds are very rare, R.Khodabakhshian did a compression test[7],but the amount of data in their test is very small, moisture content is less than 15%, and did not consider the impact of load speed.So,study on the mechanical characteristics of sunflower seeds is necessary.

II. MATERIALS AND METHODS

A. Materials and Equipment

The experimental materials used fresh sunflower seeds in Ya'an city, Sichuan province,no pests, shell rupture injury. Their common characteristics are: the whole is a long elliptic in somber black,both sides have crack, approximation on shell symmetry. Testing equipment mainly contains compression tester, WD-W precise micro control electronic universal testing machine(Ji'nan Fangchen Instrument Equipment Co,. Ltd,.Ji'nan,China). Electronic balance(Shanghai Ohaus Corporation.Shanghai,China).Type DHG-9146A electric constant temperature drying oven (Shanghai Suda Experimental Instrument Co,. Ltd,. Shanghai, China).

B. Methods

The test adopts horizontal (X direction), on the side (Y direction), stood on (Z direction) three different modes of loading directions. To make it stable ,we use little seconds quick drying glue.The computer display shell breaking force, deformation, displacement and other parameters during the tests.The data start showing when the disk access to the material's surface.The force drop when the sunflower seeds' shell breaking and the computer stop recording data, then display the data on the screen.

C. Data Measurement and Parameter Calculation

There are three responses in the test: the shell breaking force F, deformation S, shell breaking energy E. Among them F and S are recorded by the computer.The calculation methods of E is as following:

$$E = \frac{1}{2}\sum_{i=1}^{n}\left[\left(F_i + F_{i+1}\right)\left(S_{i+1} - S_i\right)\right] \qquad (1)$$

Because the curves of the compression process close the graph of proportional function,So the calculation of shell breaking energy can be simplified as:

$$E = \int_0^S F(S)dS \approx \frac{1}{2}F \times S \qquad （2）$$

Referencing GB/T 5497-1985[4] on the seeds moisture content determination and related literature[5] The experiment used 105℃ constant weight method to test the dry mass of sunflower seeds:

$$M_e = \frac{m - m_0}{m_0} \times 100\% \qquad (3)$$

Where, M_e is the wet basis moisture content (%), m is the initial mass(g), and m0 is the mass of absolute dry (g);

III. RESULTS AND ANALYSIS

A. Single factor test

Through single factor analysis of variance of the results,and fitting the curve with toolbox of cftool by using Matlab.

B. Significance analysis

As shown in table 1,at the loading rate of 15 mm/min ,the moisture content showed a weak significant effect on the deformation when loading on the Y direction, on the rest of the response is very significant. When the moisture content is 16.36%, the loading speed on the deformation under the direction of X is very significant, the remaining responds under X direction is not significant; Shell breaking force and energy is very significant under the direction of Y , but on the deformation is not obvious, the energy consumption under Z direction is not significant, for the rest of the response is very significant.

C. Mechanical properties of sunflower seeds with different moisture content & loading speed

As shown in Fig.1,as the water contend increase, sunflower seed shell fiber and grain moisture content rise, sunflower seed shell and seeds integral is bigger, seed and shell joint, increased breaking force.The sunflower large gap between the housing and the grain in the Y, Z directions, with increasing moisture content, fiber becomes fluffy, broken shell force drops. As the moisture content increased gradually soft the shell, but the moisture content is further increase, the larger and thicker plastic shell becomes stronger, broken shell deformation becomes larger.

As shown in fig.5, when loading under the X direction, loading speed effect on the force is not significant, but the overall force is greater than the broken shell under Y, Z directions. When loading under the Z direction, with the loading speed increase, two peaks occur at the loading speeds of 15mm / min and 30mm / min. And in the Y direction with the loading speed increase, broken shell fo-rce decrease.
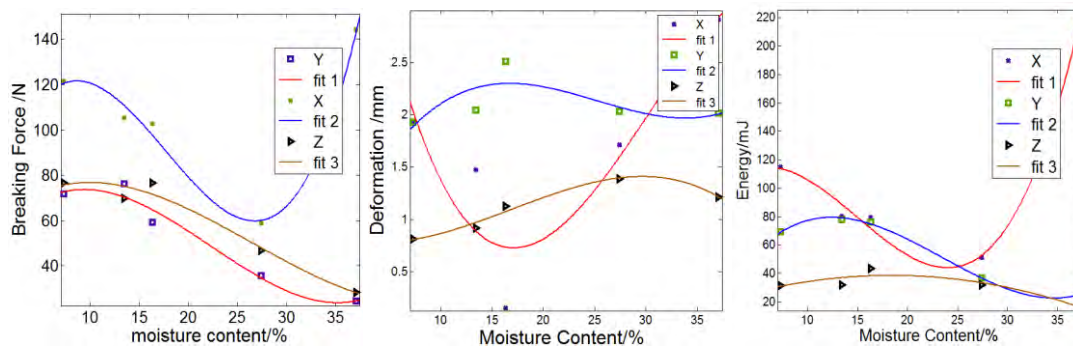

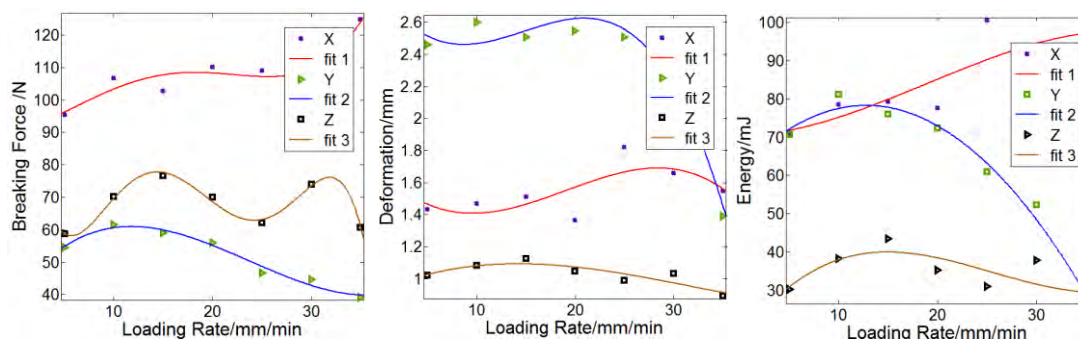Figure 1.　Sunflower mechanical properties under different moisture content

Figure 2.　Sunflower mechanical properties under different loading rate

D. Orthogonal test

Using the L9(34) orthogonal test table,each of the response index was repeated 10 times and take average value.Orthogonal test results are shown in Table2.

The three variables that affect the performance of broken shell, respectively, force, force, deformation, energy multivariate linear regression. As shown in table 3 can get broken shell performance linear regression model with three variables for(When placed horizontally in this article take D = 1, when on the side take D = 2, stand up when taking D = 3):

$$F = -.029V - 1.69C - 1.71D + 138.4$$
$$S = -0.046V + 0.011C - 0.29D + 2.043 \quad (4)$$
$$E = -0.43V - 1.09C - 21.1D + 112.7$$

E.   Index test

As shown in table 4.Three variables on the performance of the broken shell multivariate linear regression model significant at the 0.05 level.Table 4 shows p<0.05 , so the above model establishment.

IV.   CONCLUSIONS

Single factor tests showed: under various conditions,loaded from three directions X, Y, Z, when loaded to break the shell along the Y gets the minimum force, while under the Z direction loading deformation and energy consumption are minimized. When loading at the speed of 15 mm /min under all directions , the moisture content effect on the force and, energy consumption is very significant,For Y direction of energy consumption, the moisture content shows a weak significance on the deformation.

At moisture content of 16.36%, the loading speed effect on the force of Y direction is very significant; on the force under the Z direction, deformation under the direction of X and Y, and energy consumption under Y, Z directions performance a weak significance.On the force under X direction, the deformation under the Z direction, energy consumption under X direction performance no significance. Orthogonal test results showed that: broken shell strength, broken shell deformation, broken shell linear model with variable energy are: $F = -0.29v - 1.69c - 17.1d + 138.4$, $S = -0.046v + 0.011c - 0.29d + 2.043$, $E = -0.43v - 1.09c - 21.1d + 112.7$.

TABLE I.   RESULTS OF ORTHOGONAL TEST

	Factors			Results		
	Directions	Rate /mm/min	Water Contend /%	Force /N	Deformation /mm	Energy /mJ
	(A)	(B)	(C)	(F)	(S)	(E)
1	1(X)	1(5)	1(7.32)	111.23	1.47	84.59
2	1	2(20)	2(16.3)	110.15	1.37	77.73
3	1	3(35)	3(37.1)	45.57	1.91	44.87
4	2(Y)	1	2	54.60	2.46	70.74
5	2	2	3	22.04	2.18	24.49
6	2	3	1	66.02	1.95	65.39
7	3(Z)	1	3	33.43	1.23	21.05
8	3	2	1	70.05	0.89	32.36
9	3	3	2	60.76	0.89	27.25

TABLE II.   VARIABLE LINEAR REGRESSION MODEL TO THE CORRESPONDING INDEX

Performance	R.C	Confidence Interval	R^2	F	SS	P
F /N	β_0=138.4	(84.4674,192.30)	0.78	6.14	321.9	0.039
	β_1=-0.29	(-1.5542,0.9562)				
	β_3=-1.69	(-2.9325,-0.467)				
	β_4=-17.1	(-35.9469,1.710)				
D /mm	β_0=2.043	(0.2362,3.84930)	0.88	21.25	124.3	0.035
	β_1=-0.046	(-0.0466,0.0375)				
	β_3=0.011	(-0.0303,0.0523)				
	β_4=-0.29	(-0.9209,0.3409)				
E /mJ	β_0=112.7	(95.8808,149.465)	0.92	19.20	79.48	0.036
	β_1=-0.43	(-1.0556,0.19191)				
	β_3=-1.09	(-1.7009,-0.4759)				
	β_4=-21.1	(-30.4446,-11.73)				

TABLE III. VARIABLES TO TEST THE CORRESPONDING INDEX OF THE LINEAR REGRESSION EQUATION

Performance	Source	SS	df	MS	F	Prob>F	Significance
F /N	columns	75338	8	9417	22.09	0	***
	error	34537	81	426.3			
	total	109875	89				
D /mm	columns	25.02	8	3.12	14.44	0	***
	error	17.54	81	0.21			
	total	42.56	89				
E /mJ	columns	49755	8	6219	9.55	0	***
	error	52735	81	651.1			
	total	102490	89				

Note: * * * to represent significant difference at 0.05 level

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